

## Description

# *Headset Detector in a Device Generating Audio Signals*

### BACKGROUND OF INVENTION

[0001] *Field of the Invention*

[0002] The present invention relates to devices such as smart phones which generate audio signals, and more specifically to a headset detector in such a device.

[0003] *Related Art*

[0004] Devices such as radios, mobile phones, MP3-players, tape recorders often generate audio signals (e.g., music or voice). In a typical scenario, an analog signal (or digital data) representing the audio signal is received either from a local medium (e.g., audio tape, laser disk) or from an external source (e.g., network, air), and audio signals is generated for the users.

[0005] Headsets are often used associated with such devices. A headset generally refers to an apparatus which has one or

more earphones that can be placed in the proximity of the ears of a user, and the audio signals generated by the device can be heard by the user by inserting a pre-specified end into the device. The audible signals are received through the headset and heard by the user having an earphone close to the ear.

- [0006] A device may contain a headset detector to provide various features. For example, a prior embodiment may contain a mechanical switch which moves into a specific position when a headset is inserted into the device, and a headset detector detects the presence of the headset based on the position of the mechanical switch. The device may operate differently (e.g., play audio signals only through the headset if the headset is present) depending on whether the headset is detected to be present or absent.
- [0007] One problem with such a mechanical switch based solution is that mechanical implementations are generally susceptible to failure and the complexity of integrating the corresponding solutions into electrical/electronic devices is high. In addition, the mechanical implementations are generally space consuming. At least for some of such reasons, it is generally desirable to provide an improved

approach by which the presence (upon insertion) of a headset can be detected.

- [0008] In addition, it may be desirable for the headset detector to detect the type of headset inserted into the device. As is well known, headsets are of multiple types, each generally suited for specific devices and environments. For example, a stereo headset contains two speakers and no microphone, can be used to play music, and is suited for use associated with and MP3 player type of devices. On the other hand, a cellular headset used associated with mobile phones contains a speaker and a microphone, and enables a user to place/answer a call. As another example, a stereo+cellular headset contains two speakers and a microphone, and can be used as a combination of stereo and cellular headsets.
- [0009] Once the headset type is detected, a device may interface as suited for the specific headset. Such a feature may be particularly useful in devices such as smart phones which may operate as cell phone, MP3 player, radio, etc., and a single/common jack may be provided to insert any of the headset types. Based on the type of headset detected to be present in the jack, a device can operate to perform only the specific features supported by the headset. Ad-

vantages such as using all the available resources (e.g., electrical power, processing power) only for the relevant features may be attained as a result.

## **BRIEF DESCRIPTION OF DRAWINGS**

- [0010] The present invention will be described with reference to the following accompanying drawings.
- [0011] Figure (Fig.)1 is a block diagram illustrating an example device in which the present invention may be implemented.
- [0012] Figure 2A is a diagram illustrating the details of a jack suitable for a stereo headset in one embodiment.
- [0013] Figure 2B is a diagram illustrating the details of a jack suitable for a cellular headset in one embodiment.
- [0014] Figure 2C is a diagram illustrating the details of a jack suitable for a stereo+cellular headset in one embodiment.
- [0015] Figure 3A is a connection diagram illustrating the details of connections for stereo headset to a common jack in one embodiment.
- [0016] Figure 3B is a connection diagram illustrating the details of connections for cellular headset to a common jack in one embodiment.
- [0017] Figure 3C is a connection diagram illustrating the details of connections for stereo+cellular headset to a common

jack in one embodiment.

- [0018] Figure 4 is a circuit diagram illustrating the details of a cap-less interface to a headset.
- [0019] Figure 5 is a circuit diagram illustrating the details of a cap interface to a headset.
- [0020] Figure 6 is a timing diagram illustrating the details of signals in cap-less interface and cap interface.
- [0021] Figure 7 is a circuit diagram illustrating the details of a detector circuit with a cap-less interface in an embodiment of the present invention.
- [0022] Figure 8 is a timing diagram illustrating the details of a detect pulse in an embodiment of the present invention.
- [0023] Figure 9 is a flowchart illustrating the manner in which headset insertion may be detected according to an aspect of the present invention.
- [0024] Figure 10 is a flowchart illustrating the manner in which type of headset may be detected according to an aspect of the present invention.
- [0025] Figure 11 is a flowchart illustrating the manner in which button press and headset removal may be detected in headsets with a microphone according to an aspect of the present invention.
- [0026] Figure 12 is a flowchart illustrating the manner in which

headset removal may be detected in stereo headset according to an aspect of the present invention.

[0027] Figure 13 is a circuit diagram illustrating the details of a detector circuit with cap- interface in an embodiment of the present invention.

## DETAILED DESCRIPTION

[0028] *1. Overview*

[0029] A headset detector provided according to an aspect of the present invention determines whether a headset is present in a jack by measuring the impedance between at least a pair of the connection points of the jack. signal may be generated with a first logical value if the headset is determined to be present, and with the other logical value otherwise. Due to such a feature, the presence of a headset in the jack can be detected without potentially using mechanical movement (as noted above in the related art section) of switches, etc.

[0030] According to another aspect of the present invention, a type of headset inserted into a jack may be determined by measuring the impedance between various connection points of the jack. In one embodiment, a headset detector determines whether an inserted headset is a stereo head-

set, cellular headset or stereo+cellular headset.

[0031] Various aspects of the present invention are described below with reference to an example problem. Several aspects of the invention are described below with reference to examples for illustration. It should be understood that numerous specific details, relationships, and methods are set forth to provide a full understanding of the invention. One skilled in the relevant art, however, will readily recognize that the invention can be practiced without one or more of the specific details, or with other methods, etc. In other instances, well-known structures or operations are not shown in detail to avoid obscuring the invention.

[0032] *2. Example Environment*

[0033] Figure 1 is a block diagram illustrating an example environment in which various aspects of the present invention may be implemented. The environment is shown containing device 110 and headset 190. Device 110 is further shown containing central processing unit (CPU) 120, detector circuit 130, control register 140, headset interface circuit 150 and jack 160. Only the relevant components to describe the present invention in device 110 are shown, however, device 110 may contain many other components. Each component is described below.

[0034] Headset 190 can be any one of various types of headsets (an end of) which can be inserted in jack 160. In one embodiment, the headset types include stereo headset, cellular headset and stereo+cellular headset. The description is provided with only three types of headsets for illustration, however, headset 190 may include other types of headsets without departing from the scope and spirit of various aspects of the present invention.

[0035] Jack 160 is designed to receive various types of headset. In one embodiment, jack 160 supports any type of headset with 3-wires or 4-wires (as described below in further detail with respect to Figure 2). By using a common jack for different headset types, the space and component requirements in device 110 may be reduced.

[0036] Headset interface circuit 150 provides an interface between headset 190 and detector circuit 130. Typically, two types of headset interface circuits are used – cap interface and cap-less interface, which are further described in detail in sections below. Due to various features of the present invention, headset interface circuit 150 may be implemented without requiring mechanical components (i.e., position of switch moving physically) noted in the background section above.

[0037] Control register 140 contains bits (memory) to store data representing various status information determined by detector circuit 130. For example, control register 140 stores the bits representing headset detection, headset removal, type of headset, button press detection (in the case of cellular and stereo+cellular headset, as described in sections below), etc.

[0038] CPU 120 controls various operations of the components in detector circuit 130 based on the status indicated in control register 140 and interrupts received from detector circuit 130 on path 123. For example, CPU 120 sends control signal on path 123 to power down the components in detector circuit 130 until insertion of headset is detected if headset detection bit in control register 140 indicates headset is not inserted in a jack.

[0039] Detector circuit 130 may detect the type of headset inserted, insertion/removal of headset, button press, etc., according to various aspects of the present invention. Detector circuit 130 updates the corresponding bits in control register 140. In addition, detector circuit 130 sends interrupt signals to CPU 120 on path 123 upon detection of various events (insertion of headset, etc.).

[0040] The operation of detector circuit 130 depends on the spe-

cific structure of jack 160. As noted above, jack 160 is used as a common jack for all three types of headset. Thus, it is helpful to understand the structure of various types of jacks in general.

[0041] *3. Jacks*

[0042] Figures 2A, 2B and 2C are diagrams together illustrating the details of various jacks suitable for different types of headsets. In particular, Figure 2A is shown containing jack 210, Figure 2B is shown containing jack 220 and Figure 2C is shown containing jack 240. Jacks 210, 220 and 240 are respectively suitable for stereo headset, cellular headset and stereo+cellular headset. In Figures 2A, 2B and 2C, the notation g, m, and s respectively represent connection points to ground, microphone and speaker(s) in headsets.

[0043] Jack 210 is shown containing connection points represented as g, s and s. Two speakers in stereo headset can be connected to s and s connection points, and ground can be connected to g point. Jack 220 is shown containing connection points g, m and s. Microphone and speaker in cellular headset are connected to m and s points respectively. Similarly, jack 240 is shown containing connection points g, m, s and s. Two speakers and microphone in stereo+cellular headset are connected to s, s and m re-

spectively.

[0044] Jack 240 can be used as a common jack to connect all kinds of headsets since jack 240 contains four connection points, which would provide connections to a 3-wire/4-wire headsets. A jack of type jack 240 may be used for jack 160 of Figure 1. However, jacks 210 or 220 may be used for jack 160 for some aspects of the present invention. The connection diagram for different headsets to the common jack (240) is described below with reference to Figure 3.

[0045] *4. Connection of Various Headsets to a Common Jack*

[0046] Figures 3A, 3B and 3C are connection diagrams together illustrating the details of connections for various headsets to a common jack in one embodiment. In particular, Figure 3A illustrates the connections of stereo headset 310 to common jack 240, Figure 3B illustrates the connections of cellular headset 320 to common jack 240 and Figure 3C illustrates the connections of stereo+cellular headset 340 to common jack 240. Each of stereo headset 310, cellular headset 320 and stereo+cellular headset 340 may be used in the position of headset 190 of Figure 1.

[0047] With reference to Figure 3A, stereo headset 310 is shown containing speakers 311 and 312. Each speaker 311 and

312 in turn contains two terminals s and g. The s terminal from each speaker 311 and 312 is connected to each of s (connection) points on jack 240 and g terminal from both speakers 311 and 312 is connected to g point on jack 240. In addition, the g point and m point on jack 240 are connected since stereo headset 310 does not contain microphone.

- [0048] With reference to Figure 3B, cellular headset 320 is shown containing speaker 321, microphone 322, resistor 323 and button 324. Resistor 323 and button 324 are connected in sequence and together are connected in parallel to microphone 322. Resistor 323 has a small resistance value, for example, 100 ohms. Button 324 is used to start or stop a call (depending on the prior state).
- [0049] Speaker 321 in turn contains two connecting terminals s and g, and microphone 322 contains connecting terminals m and g. The s terminal of speaker 321 is connected to one s point on jack 240, m terminal of microphone 322 is connected to m point on jack 240 and g terminal from both speaker 321 and microphone 322 is connected to g point on jack 240. The another s point on jack 240 remains floating (no connection) since cellular headset 320 contains only one speaker.

[0050] With reference to Figure 3C, stereo+cellular headset 340 is shown containing speakers 341 and 342, microphone 343, resistor 344 and button 345. Resistor 344 and button 345 operate similar to resistor 323 and button 324 of cellular headset 320 respectively. Each speaker 341 and 342 in turn contains two connecting terminals s and g and microphone 343 contains connecting terminals m and g. The s terminal of each speaker 341 and 342 is connected to each of s point on jack 240, m terminal of microphone 343 is connected to m point on jack 240 and g terminal from speakers 341 and 342, and microphone 343 is connected to g point on jack 240.

[0051] Headsets are connected to detector circuit 130 through headset interface circuit 150. The description is continued with reference to example headset interface circuits.

[0052] *5. Headset Interface*

[0053] Figures 4, 5 and 6 together illustrate the details of headset interface circuit 150 in one embodiment. Merely for illustration, headset interface with stereo headset 310 is described, however, similar approaches can be used with other types of headsets. Two types of headset interfaces are typically used -cap-less interface and cap interface, which are further described below with reference to Fig-

ures 4 and 5 respectively.

[0054] Figure 4 is a circuit diagram illustrating the details of cap-less interface 400 with headset 310 in one embodiment. In comparison to capacitor-based interface of Figure 5 (described below), cap-less interface 400 does not contain capacitors (cap). Stereo headset 310 receives a signal representing the audio (e.g., Music) to be played by speakers 311 and 312 on paths 411 and 412.

[0055] In general, the signal on paths 411 and 412 changes both in positive and negative directions with reference to a common voltage ( $V_{mid}$ ) such that the average value is zero. The g terminal of speakers 311 and 312 is connected to a voltage equal to  $V_{mid}$ . The difference of voltage levels on g ( $V_{mid}$ ) and s terminals (signals on paths 411 and 412) would cause the signal across speakers 311 and 312 to change with respect to zero voltage level and any D.C. ( $V_{mid}$ ) voltage does not appear across speakers. The D.C. voltage otherwise applied to speakers would decrease the life time of speakers.

[0056] Figure 5 is a circuit diagram illustrating the details of a cap interface connected to headset 310 in one embodiment. Cap interface 500 is shown containing capacitors 510 and 520. Capacitors 510 and 520 receive the audio

signal on paths 511 and 512 respectively. The signals on paths 511 and 512 are similar to signal on paths 411 and 412 of Figure 4 respectively. Each capacitor 510 and 520 block the D.C. (direct current) voltage ( $V_{mid}$ ) and provides only the changes in the signal with respect to zero voltage on paths 513 and 523.

- [0057] Stereo headset 310 receives a signal representing the audio (e.g., Music) to be played by speakers 311 and 312 on respective paths 513 and 523. The g terminal of speakers 311 and 312 is connected to ground. As a result, the signal on paths 513 and 523 does not contain D.C. components. The D.C. components otherwise applied to speakers would decrease life time of speakers. The manner in which various signals would change is described below.
- [0058] Figure 6 is a timing diagram illustrating the details of various signals in cap-less interface 400 and cap interface 500. Line 610 represents the audio signals received on each of paths 411 and 412 of Figure 4 and 511 and 512 of Figure 5. It may be appreciated that lines 610 and 630 are shown as sinusoidal signals merely for illustration. In reality, the shape is determined by the audio signals.
- [0059] Line 630 represents the signal that would appear across each of speakers 311 and 312 of Figure 4 and on paths

513 and 523 of Figure 5. Line 610 changes with respect to a common voltage level of Vmid such that the average value is zero. With respect to Figure 5, line 630 changes with respect to zero voltage level due to dc blocking in cap interface 500. With respect to Figure 4, line 630 changes with respect to zero voltage due to the Vmid voltage applied to g terminal of speakers 311 and 312.

[0060] Detector circuit 130 performs various operations in accordance with various aspects of the present invention, in addition to providing the audio signals to speakers 311 and 312. The manner in which detector circuit 130 may be implemented with cap-less interface is described first with reference to Figure 7, and with cap interface is described later with reference to Figure 13.

[0061] *6. Detector circuit with cap-less Interface*

[0062] Figure 7 is a circuit diagram illustrating the details of detector circuit 130 with cap-less interface 400 in an embodiment of the present invention. Merely for illustration, all of headsets 310, 320 and 340 are shown connected to detector circuit 130, however, only one of headsets 310, 320 and 340 is connected at any instant of time.

[0063] Detector circuit 130 is shown containing resistors 710-1 through 710-4 and 786, comparators 720, 725 and 730,

AND gates 740 and 745, speaker drivers 760 and 765, micbias driver 770, ground voltage driver 775, mic amplifier 780, capacitor 785, and switches 790-1 through 790-4. Each component is described below in further detail.

- [0064] Resistors 710-1 through 710-4 form a voltage divider network. The voltage divider network divides the voltage (Vbias) received at node 779 into two reference voltage levels equaling  $7*Vbias/8$  (wherein '\*' represents multiplication factor) and  $Vbias/8$ , and provides the two reference voltage levels on respective paths 712 and 713. As will be clear from the description below, Vbias is provided by one of micbias driver 770, Vdd (via switch 790-1) and detect pulse on path 792 (via switch 790-2).
- [0065] Speaker driver 760 drives the specific one of present speakers 311, 321 and 341, with the signal representing audio/music to be played. Speaker driver 765 drives specific one of speakers 312 and 342 in case the inserted headset is of stereo or stereo+cellular type, with the signal representing audio/music to be played.
- [0066] Ground voltage driver 775 provides the required ground voltage (for example, Vmid as described above with reference to Figure 4) to the inserted headset. The ground

voltage may be generated using power supply (not shown) and may be implemented in a known way. Micbias driver 770 provides the required bias voltage to microphones 322 and 343, in case the inserted headset is of headsets 320 (cellular) and 340 (stereo+cellular) type respectively. The signal representing the audio received from microphones 322 and 343 is provided at node 728.

- [0067] Resistor 786 and capacitor 785 together process the audio signal received from the specific one of microphones 322 and 343. In particular, resistor 786 provides the required bias to microphones 322 and 343 and capacitor 785 filters any DC (direct current) component in the received audio signal at node 728. Mic power amplifier 780 amplifies the d.c filtered audio signal and provides the amplified signal to analog to digital converter (not shown) for further processing.
- [0068] The remaining components of Figure 7 are described with reference to each detection feature provided by detector circuit 130. Broadly, the features include detecting each of presence of headset, type of headset inserted, and button press in headset.
- [0069] *7. Presence of Headset*
- [0070] The principle underlying the detection of whether a head-

set is present in a jack, can be understood by appreciating that the impedance between a pair of connection points in a jack is different with the presence and absence of a headset in the jack. For example, the absence of headset causes high impedance since the connection points are not connected and the presence of headset reduces the impedance since headset provides connection between connection points.

- [0071] Thus, the presence of headset in a jack may be determined by measuring the impedance between at least a pair of the connection points of the jack. For example, the impedance is measured between g and m connection points of a jack. A signal may be generated with a first logical value if the headset is determined to be present, and with the other logical value otherwise. Due to such a feature, the presence of a headset in the jack can be detected without potentially using mechanical movement of switches as described below in further detail.
- [0072] Continuing with reference to Figure 7, micbias driver 770 generates the bias voltage (micbias) to operate microphone in headset. The bias voltage may be generated using power supply (not shown) and may be implemented in a known way. Switch 790-1 is opened if micbias driver

770 is turned on, else switch 790-1 is closed such that either Vdd or micbias is provided as Vbias at node 779. Switch 790-3 is closed, which connects node 797 to Vss (ground).

- [0073] Comparator 720 generates on path 722 a signal having one logical value if a headset is present in jack 240 and another logical value otherwise. Comparator 720 compares the voltage on node 728 with the voltage (7\*Vbias/8) received on path 712 and provides the comparison result as headset\_detect on path 722. The result on path 722 indicates whether headset is present in jack (240) or not, as described below in further detail.
- [0074] If headset is not present in jack 240, the voltage on node 728 equals Vbias since nodes 728 and 797 are not connected. In such a situation, headset\_detect on path 722 is 0 (corresponding one comparison result) since (7\*Vbias/8) on path 712 is less than Vbias on node 728. If headset is present in jack 240, the voltage on node 728 would be below (7\*Vbias/8) due to the impedance (represented by Rmic) provided by the headset between nodes 728 and 797. The voltage on node 728 may be given by equation (1) below.
- [0075] Voltage on node 728 = Vbias  $(R_{mic}/(R_{mic} + R786))$  Equa-

tion (1)wherein R786 represents the resistance of resistor 786 connected between nodes 779 and 728.

[0076] In an embodiment, R<sub>mic</sub> equals 3Kilohms and R786 is chosen as 2.2Kilohms. As a result the voltage on node 728 would approximately equal half of V<sub>bias</sub>. Due to such low voltage on node 728, a value of 1 is provided on headset\_detect 722, indicating that headset is present in jack 240. Therefore, a 1 on headset\_detect 722 indicates the presence of headset and a 0 indicates the absence of headset.

[0077] Even though the removal/absence of headset may be detected as described above, an aspect of the present invention reduces power consumption to detect removal of a headset after the headset is determined to be present, as described below in further detail.

[0078] *8. Detecting Removal of Headset while Reducing Power Consumption*

[0079] As described above, headset removal may be detected by applying voltage V<sub>bias</sub> at node 779 continuously while performing detection, which may consume substantial power. However, according to an aspect of the present invention, voltage V<sub>bias</sub> at node 779 may be provided for a short duration by using a detect pulse (detect pulse is de-

scribed in sections below with reference to Figure 8). As a result, current flows through various components in detector circuit 130 for a short duration and thus power consumption may be reduced as described below in further detail.

- [0080] Continuing with reference to Figure 7, ground bias driver 775 provides ground bias voltage to an inserted headset, and may be implemented in a known way. If ground bias driver 775 is turned on, micbias driver 770 is also turned on (by appropriate action of CPU 120) to provide the required bias voltage to detect headset removal. In an embodiment, ground bias driver 775 provides a ground bias voltage of 1.5V, micbias driver 770 provides a micbias voltage of 3.3V and Vdd equals 1.8V.
- [0081] When ground bias driver 775 is turned on and micbias driver 770 is not turned on, the voltage applied to detector circuit 130 would equal 0.3V(1.8V-1.5V), which is small. If micbias driver 770 is turned on, the voltage would equal 1.7V(3.3-1.5), which may be enough to drive various components in detector circuit 130. If both ground bias driver 775 and micbias driver 770 are turned off, switches 790-2 and 790-3 are closed such that the required bias voltage is provided by detect pulse con-

nected on path 792. Local oscillator (not shown) may generate the detect pulse on path 792.

- [0082] As described above, if headset is inserted, the voltage at node 728 is low, which causes a 1 on path 722 indicating headset is inserted. If headset is removed, nodes 728 and 797 are not connected, which causes the voltage at node 728 to rise (approximately to Vbias). As a result, comparator 720 provides 0 on path 722, which indicates headset is removed.
- [0083] As may be appreciated from the description above, the removal of headset is checked according to the frequency of pulses on path 792, and by keeping the frequency (and/or pulse duration) low, the power consumption can be minimized.
- [0084] Once the presence of headset is detected, it may be required to detect the type of headset to perform the corresponding operations (e.g., playing music). The manner in which the type of headset may be detected is described below.
- [0085] *9. Type of Headset Detection While Reducing Power Consumption*
- [0086] The principle underlying the detection of type of headset can be understood by appreciating that the impedance between various connection points in a jack varies for var-

ious types of headsets. For example, the impedance between g and m connection points of a jack is small for stereo headset since g and m terminals of stereo headset is shorted and high for both cellular and stereo+cellular headsets due to the presence of microphone between g and m terminals as shown in Figures 3A, 3B and 3C. Thus, stereo headset may be detected by measuring impedance between g and m connection points.

- [0087] Cellular headset is differentiated from stereo+cellular headset by measuring impedance between s and g connection points. Cellular headset offers high impedance between s and g connection points since s connection point is floating (not connected). Stereo+cellular headset offers low impedance due to the presence of a speaker between s and g terminals. Thus, cellular headset may be differentiated from stereo+cellular headset due to the variation in impedance between s and g connection points, as described below in further detail.
- [0088] Continuing with reference to Figure 7, comparator 725 generates signals indicating whether the headset is stereo headset or not, and comparator 730 generates signals indicating whether the headset is cellular headset or not. If the headset is neither stereo headset 310 nor cellular

headset 320, that indicates the headset is stereo+cellular headset 340. The manner in which the headset may be detected as stereo headset 310 or not is described first below.

[0089] Comparator 725 compares the voltage on node 728 with the voltage  $V_{bias}/8$  received on path 713 and provides the comparison result on path 724. AND gate 745 provides the inversion of the result 724 on path 755 as `stereo_hs` when `headset_detect` is 1. The result on path 755 indicates whether headset is stereo headset or not as described below.

[0090] While detecting headset type, switches 790-1 and 790-3 are closed (by CPU 120) in case `headset_detect` path 722 indicates that a headset is inserted in jack 240, thereby forming a path from  $V_{dd}$  to  $V_{ss}$  through m and g terminals of the inserted headset. If the inserted headset is of stereo headset (310) type, g and m terminals are shorted, which causes the voltage at node 728 to equal  $V_{ss}$ . In such a situation, comparator 725 provides 0 on path 724 since the voltage on node 728 is less than  $V_{bias}/8$  received on path 713. A 0 on path 724 causes a 1 on path 755, which indicates that the inserted headset is of stereo headset (310) type.

[0091] If the inserted headset is not of stereo headset type, connection points g and m of jack 240 are connected to microphone 322 in case the inserted headset is of cellular headset type, and to microphone 343 in case the inserted headset is of stereo+cellular headset type. Each microphone 322 and 343 may provide a relatively high resistance (in one embodiment equaling approximately 3.0 kilohms) compared to in the case of stereo headset type, which causes the voltage on node 728 to approximately equal  $V_{bias}/2$ .

[0092] In such a situation, comparator 725 provides 1 on path 724 since the voltage on node 728 could be higher than  $V_{bias}/8$  received on path 713. A 1 on path 724 causes a 0 on path 755, which indicates that the inserted headset is not of stereo headset (310) type. The manner in which whether an inserted headset is of cellular headset (320) type or not is described below.

[0093] Comparator 730 compares the voltage on node 796 with the voltage  $V_{bias}/8$  received on path 713 and provides the comparison result on path 734. AND gate 740 provides the result 734 on path 744 as cell\_hs when headset\_detect path 722 is 1. The result on path 744 indicates whether the inserted headset is of cellular headset type or

not as described below.

[0094] Switches 790-3 and 790-4 are closed (by CPU 120) in case headset\_detect path 722 indicates that a headset is inserted in jack 240 and stereo\_hs path 755 indicates that the inserted headset is not of stereo headset type. In case the inserted headset is of cellular headset (320) type, node 796 is not connected to cellular headset 320, which causes Vdd to appear at node 796 due to the connection of node 796 to Vdd through switch 790-4. In such a situation, comparator 730 provides 1 on path 734 since the voltage on node 796 is higher than Vbias/8 received on path 713. A 1 on path 734 causes a 1 on path 744, which indicates the inserted headset is of cellular headset (320) type.

[0095] If the inserted headset is not of cellular headset type and if headset\_detect 722 indicates that a headset is present, the speaker (of stereo headset 310 and stereo+cellular headset 340, as the case may be) is connected between connection points s and g of jack 240. The connection points s and g are in turn connected to respective nodes 796 and 797. In an embodiment, speaker offers a low resistance in the range of 16ohms to 64ohms, which pulls the voltage on node 796 to voltage equaling Vss. In such a

situation, comparator 730 provides 0 on path 734 since the voltage on node 796 is less than  $V_{bias}/8$  received on path 713. A 0 on path 734 causes a 0 on path 744, which indicates the inserted headset is not of cellular headset (320) type.

- [0096] If both stereo\_hs 755 (i.e., inserted headset is not of stereo headset type) and cell\_hs (not of cellular headset type) 744 are 0, then the inserted headset is detected as being of stereo+cellular headset (340) type. The results on paths 722, 755 and 744, which respectively indicate headset detection, headset is either stereo headset type or cellular headset type, are stored in control register 140 for further processing by CPU 120 of Figure 1.
- [0097] It may be noted that the inserted headset in jack 240 is removed and another headset or same headset is inserted back, then detector circuit 130 detects the type of the headset inserted in jack 240 without having to initialize (reboot, power-up, etc.) device 110.
- [0098] Once the type of headset is detected, it may be required to perform different operations depending on the type of headset inserted. For example, music/audio may need to be played in case the inserted headset is of stereo headset type and answer a phone call in case the inserted headset

is of cellular headset type, etc. However, some of the operations may not be performed until button (324 /345) is pressed in case of inserted headset is detected to be of cellular headset 320 or stereo+cellular headset 340 type. The manner in which the pressing of the button (hereafter "button press") may be detected is described below.

[0099] *10. Button Press Detection*

[0100] The principle underlying the detection of button press can be understood by appreciating that the impedance between a pair of connection points to which a button is connected is different with button press and without button press in a headset. For example, impedance is high if button is not pressed since switch 324 or 345 (in Figures 3B and 3C respectively) is open. The impedance is low if button is pressed since the switch is closed causing an impedance equaling the impedance of resistor 323 or 344 between the connection points. The button is momentarily pressed and released to initiate or end a call.

[0101] Thus, button press may be detected momentarily by measuring the impedance between a pair of the connection points of the jack.example, the impedance is measured between g and m connection points of a jack since the button is connected between g and m connection points

in each of cellular headset 320 and stereo+cellular headset 340. The manner in which button press may be detected is described in further detail below.

- [0102] Comparator 725 generates on path 755 signals indicating whether button is pressed or not. It may be appreciated from the description above, that the same path 755 is also used to indicate whether the headset is stereo headset or not. The same path is conveniently being used for both the purposes since once the type of headset is detected, the type of headset detection may not be performed again until the headset is removed and (potentially a different one) inserted.
- [0103] Comparator 725 compares the voltage on node 728 with the voltage  $V_{bias}/8$  received on path 713 and provides the comparison result on path 724. AND gate 745 provides the inversion of the result 724 on path 755 as button\_det (indicating whether the button is pressed or not) when headset\_detect is 1, as described below.
- [0104] If button is not pressed, then the resistance (in the range of 3.0kilo ohms) offered by the inserted headset between nodes 797 and 728 is only due to microphone. Due to the resistance of headset, the voltage at node 728 would approximately equal  $V_{bias}/2$ . In such a situation, compara-

tor 725 provides 1 on path 724 since the voltage on node 728 is higher than  $V_{bias}/8$  received on path 713. A 1 on path 724 causes a 0 on path 755, which indicates button is not pressed.

[0105] If button is pressed, then the resistance offered by the inserted headset between nodes 797 and 728 is due to the parallel combination of microphone (322 or 343) and resistor (323 or 344). In an embodiment, the resistance of each resistor 323 and 344 is small and is 100ohms. Due to the small resistance of resistors, the voltage at node 728 would approximately equal  $V_{gnd}$  at node 797, which is much less than  $V_{bias}/8$ . As a result, comparator 725 provides 0 on path 724, which causes a 1 on path 755, indicating that the button is pressed.

[0106] From the above, it may be noted that detector circuit 130 may detect the presence of headset, type of headset, and button press. It may be further noted that detector circuit 130 may not require a mechanical switch, for example, to perform detection or to interface with an inserted headset. In addition, detector circuit 130 may consume less power to perform detection as described below.

[0107] *11. Power Consumption Reduction*

[0108] According to an aspect of the present invention, power

consumed by device 110 may be reduced in two scenarios -(1) when headset is not present in jack 240; and (2) when device 110 is in inactive states such as standby mode. The manner in which power consumption can be reduced is described below.

- [0109] When no headset is inserted into jack 240, it is generally not required to drive the components which generate audio signals. Thus, components which perform operations such as playing, may be powered down until a headset is inserted. An aspect of the present invention takes advantage of such a requirement to reduce power consumption as described below.
- [0110] Current may be provided only to the components that detect the presence of headset (if a headset is determined not to be already present), but not to other components. Such a result may be appreciated by observing that no path exists for current in detector circuit 130 if headset is not inserted since nodes 728 and 797, which are respectively connected to Vdd and Vss, are not connected.
- [0111] Even if comparator 725 is also connected to node 728, comparator 725 does not consume current since comparators 725 and 730 are turned on by CPU 120 only when headset\_detect on path 722 indicates the presence

of headset. Therefore, only comparator 720 consumes power until a headset is inserted in a jack and the power consumed by comparator 720 is small. As a result, minimal power is consumed when headset is not present in jack 240.

- [0112] With respect to power consumption reduction in inactive state (such as standby mode) and waiting for button press, it is generally not required to drive the components which process a call. For example, when a user is driving, the user may not be able to initiate or end a call even if headset is inserted until the button is momentarily pressed and released. Thus, components which perform operations such as processing a call, may be powered down until button press is detected.
- [0113] Such a result may be achieved by noting that detector circuit 130 detects button press as described above and the components (such as mic amplifier 780, speaker drivers 760 and 765, and ground bias driver 775) that process a call are powered down until button press is detected. Due to such detection and powering down, the power consumed by device 110 may be reduced. Additional reduction in power consumption may be attained as described below with reference to Figure 8.

[0114] *12. Detect Pulse*

[0115] Figure 8 is a timing diagram of a detect pulse used to reduce power consumption in an embodiment of the present invention. The detect pulse may be provided on path 792 of Figure 7. The detect pulse is used to reduce power consumption in some situations whether substantial power may otherwise be consumed. For example, in case of detecting headset insertion, detector circuit 130 may not consume substantial power since no direct path is present between Vdd and Vss until headset is inserted in jack 240. However, in case of headset removal and button press detection, headset is already present in jack 240, which forms a path and may thus cause substantial power consumption in various components of detector circuit 130.

[0116] Thus, in an embodiment, detect pulse on path 792 is applied to detect headset removal and button press, but not in the case of detecting headset insertion. As described above, detect pulse 810 is used to provide the bias voltage (or current) when both micbias driver 770 and ground bias driver 775 are turned off to determine headset removal and button press.

[0117] The voltage level of detect pulse (on a time scale) is rep-

resented by line 810. Line 810 is shown containing low period pulse 820, which is shown repeated after a long duration at time point 815. Since only detect pulse provided on path 792 is the source of power for detector circuit 130, the total power consumed is determined by the period of detect pulse 820. By choosing a low period for detect pulse 820, the power consumption can accordingly be reduced. The reduction in power consumption may be quantified as described below.

- [0118] In an embodiment, the time duration of low period pulse 820 would approximately equal 15 $\phi$ s and the time period of the detect pulse between time points 811 and 815 is 500 $\phi$ s. The current that would flow through microphone 322 (or 343) equals 300 $\phi$ A. The average current that would be consumed by microphone 322 (or 343) due to the use of detect pulse 792 is 9 $\phi$ A ( $300*15/500 = 9$ ). A local oscillator that generates detect pulse 792 consumes around 25 $\phi$ A and various components in detector circuit 130 consume around 10 $\phi$ A.
- [0119] Therefore, total power consumption to perform detection is around 44 $\phi$ A only ( $=25+10+9$ ). In contrast, without use of the detect pulse (and providing continuous bias voltage), the power consumption could be 310  $\mu$ A. Accord-

ingly, power consumption is reduced according to an aspect of the present invention.

[0120] Thus, detector circuit 130 can be used to detect the presence of headset, the headset type, etc., while consuming minimal power. However, the operation of various components (e.g., switches) of detector circuit 130 may need to be coordinated to attain such features. The manner in which CPU 120 may perform such coordination is described with reference to each feature.

[0121] *13. Method of Detecting Headset Presence*

[0122] Figure 9 is a flowchart illustrating the manner in which the presence of a headset in a jack may be detected according to an aspect of the present invention. Steps 910–980 of the flowchart may be performed by CPU 120. The method begins in step 901, in which control immediately passes to step 910.

[0123] In step 910, switch 790–2 may be opened, for example when device 110 is reset at the time of power on. In step 920, switch 790–3 is closed to provide connection to Vss or ground. In step 930, a determination is made as to whether micbias driver 770 is turned on. As noted above, micbiad driver 770 provides the bias voltage to various components in detector circuit 130. If micbias driver 770

is turned on, control passes to step 950, else control passes to step 940.

- [0124] In step 940, switch 790-1 is closed to provide bias voltage from Vdd since micbias driver 770 is not turned on. Control then passes to step 980. In step 950, switch 790-1 is opened since micbias driver 770 provides the required bias voltage. Control passes to step 980.
- [0125] In step 980, a determination is made as to whether headset is present in a jack. As described above with reference to Figure 7, comparator 720 provides a logic value on path 722 indicating whether headset is present in a jack or not. Control passes to step 990 if a headset is present, else control passes to step 920.
- [0126] In step 990, detector circuit 130 sends an interrupt to CPU 120 and sets bit representing headset\_detection to 1 in control register 140. CPU 120 uses the status on headset\_detection and sends control signals to perform various operations accordingly. The method ends in step 999. The description is continued with reference to a method in which the type of headset may be detected.
- [0127] *14. Method of Detecting Type of Headset*
- [0128] Figure 10 is a flowchart illustrating a method in which the type of headset inserted in a jack may be detected ac-

cording to an aspect of the present invention. All steps except steps 1050, 1080 and 1090 may be performed by CPU 120. The method begins in step 1001, in which control immediately passes to step 1005.

- [0129] In step 1005, switch 790-3 is closed to provide connection to Vss or ground. In step 1010, a determination is made as to whether micbias driver 770 is turned on to provide the bias voltage to various components in detector circuit 130. If micbias driver 770 is turned on, control passes to step 1030, else control passes to step 1020.
- [0130] In step 1020, switch 790-1 is closed to provide bias voltage from Vdd since micbias driver 770 is not turned on. Control then passes to step 1040. In step 1030, switch 790-1 is opened since micbias driver 770 provides the required bias voltage. Control again passes to step 1040.
- [0131] In step 1040, a determination is made as to whether headset is of stereo headset type. As described above with reference to Figure 7, comparator 725 and AND gate 745 together provide a logic value on path 755 indicating whether headset is stereo headset or not. Control passes to step 1050 if headset is detected to be of stereo headset type, else control passes to step 1060.
- [0132] In step 1050, detector circuit 130 sets a bit in control

register 140 to indicate that a stereo headset type has been detected. CPU 120 uses the status on stereo\_hs bit and sends control signals to perform various operations accordingly. In addition, detector circuit 130 opens switch 790-1 to reduce power consumption. Control then passes to step 1099.

- [0133] In step 1060, switch 790-4 is closed to provide supply voltage to speakers in a headset to determine whether the headset is cellular or stereo+cellular headset. Control passes to step 1070, in which a determination is made as to whether inserted headset is of cellular headset type. Comparator 730 and AND gate 740 together provide a logic value on path 744 indicating whether headset is cellular headset or not. Control passes to step 1080 if a cellular headset type is detected, else control passes to step 1090.
- [0134] In step 1080, detector circuit 130 sets a bit indicating cellular headset in control register 140 to 1. CPU 120 uses the status on cell\_hs bit and sends control signals to perform various operations accordingly. In addition, detector circuit 130 opens switches 790-1 and 790-4 to reduce power consumption. Control passes to step 1099.
- [0135] In step 1090, detector circuit 130 sets a bit indicating

stereo+cellular headset in control register 140 to 1. If headset is determined as not being of stereo headset type in step 1040 and as not cellular headset type in step 1070, that indicates the headset is stereo+cellular headset. CPU 120 uses the status information in control register 140 and sends control signals to perform various operations accordingly. In addition, detector circuit 130 opens switches 790-1 and 790-4 to reduce power consumption. Control passes to step 1099, in which the method ends. The description is continued with reference to a method in which button press and headset removal may be detected if the headset contains a microphone.

[0136] *15. Button Press Detection and Headset Removal Detection in case of a Headset with Microphone*

[0137] Figure 11 is a flowchart illustrating the manner in which the button press and headset removal may be detected according to an aspect of the present invention. As described above, button press may need to be detected in cellular headset and stereo+cellular headset, which contain microphone. Steps 1110-1175 may be performed by CPU 120. The method begins in step 1101, in which control immediately passes to step 1110.

[0138] In step 1110, a determination is made as to whether

ground bias driver is turned on. As noted above, ground bias driver 775 provides the required ground bias voltage (for example,  $V_{mid}$ ) to speakers in headset. If ground bias driver 775 is turned on, control passes to step 1130, else control passes to step 1140.

- [0139] In step 1130, micbias driver is switched on to provide the bias voltage to various components in detector circuit 130. In addition, switches 790-3 and 790-2 are opened since micbias driver 770 and ground bias driver 775 provide the bias voltage. Control passes to step 1160.
- [0140] In step 1140, a determination is made as to whether micbias driver is turned on. If both ground bias driver 775 and micbias driver 770 are not turned on, control passes to step 1150, else control passes to step 1160.
- [0141] Steps 1150, 1155, 1175, 1180 and 1190 operate to determine button press and headset removal using the bias voltage provided by detect pulse received on path 792. Steps 1160, 1170, 1180 and 1190 operate to determine button press and headset removal using the bias voltage provided by micbias driver 770. Accordingly, button press detection and headset removal using the bias voltage from micbias driver is described first starting with step 1160.

- [0142] In step 1160, a determination is made as to whether button is pressed in the inserted headset. As described above with reference to Figure 7, comparator 725 and AND gate 745 together provide a logic value on path 755 indicating whether button is pressed or not. If button is pressed, button\_det on path 755 is at logic high (1), else logic low (0). Control passes to step 1180 if button is pressed, else control passes to step 1170.
- [0143] In step 1180, detector circuit 130 sends an interrupt to CPU 120 indicating that the button is pressed. CPU 120 performs operations (e.g., turning on/off micbias driver 770, speaker driver 760) responsive to receiving the interrupt. Control passes to step 1110 to detect the end of a call if the call is already initiated or to detect initiation of next call if previous call is already ended.
- [0144] In step 1170, a determination is made as to whether a headset is present in the jack. Headset\_detect on path 722 indicates whether a headset is present or not. Control passes to step 1110 if headset is present in the jack, else control passes to step 1190.
- [0145] In step 1190, detector circuit 130 sets bit in control register 140 and also sends an interrupt to CPU 120 indicating that the headset has been removed. Control passes to

step 1199. Steps 1110 to 1180 (all steps except 1190) are repeated until headset is removed. The description is continued with reference to button press and headset removal detection using the bias voltage provided by detect pulse.

[0146] In step 1150, switches 790-2 and 790-3 are closed to connect the detect pulse, which provides the required bias voltage to various components in detector circuit 130. Control passes to step 1155, in which a determination is made at the end of detect pulse (for example, at time point 812 of Figure 8) as to whether button is pressed. Control passes to step 1180, if button is pressed, else control passes to step 1175.

[0147] In step 1175, a determination is made at the end of detect pulse as to whether headset is present in jack 240. Control passes to step 1110 if headset is present, else control passes to step 1190. Steps 1110 to 1180 (all steps except 1190) are repeated until headset is removed. The description is continued with reference to a method in which headset removal may be detected if the inserted headset is of stereo headset type.

[0148] *16. Method of Headset Removal Detection in case of a Stereo Headset*

[0149] Figure 12 is a flowchart illustrating the manner in which

headset removal may be detected in case the inserted headset is of a stereo headset type according to an aspect of the present invention. Steps 1210–1280 may be performed by CPU 120. The method begins in step 1201, in which control immediately passes to step 1210.

- [0150] In step 1210, a determination is made as to whether ground bias driver 775 is turned on. As noted above, ground bias driver 775 provides the required ground bias voltage (for example,  $V_{mid}$ ) to speakers in headset. If ground bias driver 775 is turned on, control passes to step 1230, else control passes to step 1240.
- [0151] Broadly, steps 1240 and 1250 operate to determine whether a headset is removed (absent in jack) using the bias voltage provided by detect pulse received on path 792. Steps 1230 and 1280 operate to determine whether a headset is removed ("headset removal") using the bias voltage provided by micbias driver 770. Accordingly, headset removal detection using the bias voltage from micbias driver is described first starting with step 1230.
- [0152] In step 1230, micbias driver 770 is switched on to provide the bias voltage to various components in detector circuit 130. In addition, switches 790–3 and 790–2 are opened since micbias driver and ground bias driver provides the

bias voltage. Control passes to step 1280.

- [0153] In step 1280, a determination is made as to whether a headset is present in jack 240. Headset\_detect on path 722 indicates whether headset is present in the jack. Control passes to step 1210 if headset is present in the jack, else control passes to step 1290. Steps 1210 to 1280 are repeated until headset is removed.
- [0154] In step 1290, detector circuit 130 sets a bit in control register 140 and sends an interrupt to CPU 120 indicating that the headset is removed. Control passes to step 1299, in which the method ends. The description is continued with reference to headset removal detection using the bias voltage provided by detect pulse.
- [0155] In step 1240, switches 790-2 and 790-3 are closed to connect detect pulse to detector circuit 130, which provides the required bias voltage to various components in detector circuit 130. Control passes to step 1250, in which a determination is made as to whether the headset is present in the jack at the end of detect pulse. Control passes to step 1290 if the headset is not present, else control passes to step 1210. Steps 1210 to 1290 are repeated until the headset is removed.
- [0156] From the above, it may be noted that detector circuit with

cap less interface may detect headset insertion/removal, type of headset and button press. The description is continued with reference to a detector circuit with cap interface.

[0157] *17. Detector Circuit with Cap Interface*

[0158] Figure 13 is a circuit diagram illustrating the details of detector circuit 130 with cap- interface 500 in an embodiment of the present invention. Merely for illustration, all headsets 310, 320 and 340 are shown connected, however, only one of headsets 310, 320 and 340 is connected at any instant of time. Detector circuit 130 is shown containing resistors 1310-1 through 1310-4 and 1386, comparators 1320, 1325 and 1330, AND gates 1340 and 1345, speaker drivers 1360 and 1365, micbias driver 1370, mic amplifier 1380, capacitor 1385, and switches 1390-1, 1390-2 and 1390-4.

[0159] Resistors 1310-1 through 1310-4 and 1386, comparators 1320, 1325 and 1330, AND gates 1340 and 1345, speaker drivers 1360 and 1365, micbias driver 1370, mic amplifier 1380, capacitor 1385, and switches 1390-1, 1390-2 and 1390-4 operate similar to resistors 710-1 through 710-4 and 786, comparators 720, 725 and 730, AND gates 740 and 745, speaker drivers 760 and 765,

micbias driver 770, mic amplifier 780, capacitor 785, and switches 790-1, 790-2 and 790-4 of Figure 7 respectively, and the description is not repeated here for conciseness. The signals on paths 1379, 1312, 1313, 1322, 1344 and 1355 indicate similar signals on paths 779, 712, 713, 722, 744 and 755 of Figure 7 respectively. The differences of Figure 13 from Figure 7 are briefly described below.

[0160] Detector circuit 130 of Figure 13 does not contain ground bias driver since ground terminal of speakers in cap interface 500 is connected to ground. Thus, switch similar to switch 790-3 of Figure 7, which connects to Vss/ground is not required in Figure 13. Detector circuit 130 of Figure 13 may also be operated to detect insertion of headset, type of headset, removal of headset and button press in headset. The corresponding differences/extensions will be apparent to one skilled in relevant arts by reading the disclosure provided herein.

[0161] *18. Conclusion*

[0162] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present in-

vention should not be limited by any of the above described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.